caused that ascent becomes dispersed. Having no longer an ascensive power, it spreads laterally and downwards by the force of the gravity possessed by the unconsumed particles of carbon, or soot.

Where the ascent of the products of combustion is most rapid, and occupies in that ascent the smallest space, our chimnies are largest, and where, from the gradual dissipation of heat and partial resistance of the air, the smoke assumes a larger form, our chimnies are smallest.

The difference of combustion in the open air, and the same process in chimnies is, that in the former each particular column of rarefied air is replaced by the adjacent strata of a denser nature, thereby soon overcoming the ultimate ascent; while in the latter the column of heated air, having to pass up an air-tight chimney, is conserved for a greater length of time in its intensity, a longer column of warm air produced thereby possessing a superior power to set in motion the strata of neighbouring columns of a denser quality, and constituting what is called chimney draft.

It being a law, that *heat not radiant ascends in straight lines, a tube which departs from that form offers so many points of resistance to the ascending products.* If, therefore, rarefied air ascend in straight lines, the products of combustion ascend in like manner; and it is found that a chimney of equal diameter offers fewest points of resistance.

But, although it has been shewn that the forms of the greater number of chimnies, compared with the form of the ascending bodies, are anomalous, they are, nevertheless, when not contracted to an extreme, well adapted to the economy of dwelling houses. As apartments are warmed principally by the radiation of the fire and surrounding metal, the greater proportion of heat consequent upon combustion passes up the chimney; a slow drawing fire, therefore, answers the purpose, at a lower cost of fuel than if the tubes were normal or natural. As tubes in the natural form would produce a furnace. Nevertheless it is evident nature points out one means, at least, of improving the draft.

It is unnecessary to call attention to the condition of the external openings of chimnies in our best neighbourhoods, as it must have struck many, that something wrong in the arrangements for combustion was the cause.

Badly finished houses seldom smoke, while houses that are of superior construction do so frequently. If greater provision were made for internal ventilation, it is presumed one-half of the monstrous chimney endings might be taken down to-morrow; and if any person who has an appreciation of the beautiful or ornamental would design a chimney termination which should prevent down draft in tempestuous weather, whether the external opening be large or less large, it would confer a boon upon the architectural world, and then the other half of those unsightly objects might be removed as soon as convenient.

Chelsea. C. F.

EXPOSITION OF THE RULES FOR CALCULATING EQUILIBRATED ARCHES IN THE LINE OF A RAILWAY,

SUGGESTED BY THE NUMEROUS INSTANCES OF FAILURE WHICH HAVE LATELY BEEN RECORDED IN THE PAGES OF THE PUBLIC JOURNALS.

The numerous accidents that are daily occurring in consequence of the failure of railway bridges, viaducts, tunnels, &c., are truly alarming, and demonstrate to a certainty that there is something radically wrong, either in the principles upon which those structures are reared, or in the manner of their execution. But why should this be? seeing that theory has investigated the correct principles of construction for arches of every form, whatever may be the nature of the curves on which they are raised. There can surely be no sufficient reason adduced, why those who are intrusted with the formation of railways should not avail themselves of the rules and maxims thus gratuitously supplied to them, and thereby avoid many of those contingencies by which the public mind is agitated. The prejudice entertained by the chief engineers, architects, and builders, against the equilibrated arch with a horizontal extrados, is the more to be wondered at, that it is the very form which is best adapted for the purposes of a railway, being in reality the simplest of all the equilibrated curves, and requiring very little more labour in its construction than even the circular or elliptical forms, and others arising from the sections of a cone; it is moreover not ungraceful or inelegant in its appearance, and the circumstance of its ensuring the requisites of strength, stability, and safety, ought to speak volumes in favour of its general adoption.

There is one thing which operates powerfully against the introduction of this form in ordinary constructions, and that is the circumstance of its being a mechanical or transcendental curve; for, in consequence of this, it cannot be constructed directly from the data, as there are no means of delineating the curve by continued motion; the only method of describing it being by means of a series of coordinates, computed from an equation of a very complex form, and requiring the application of logarithms in its reduction—numbers of which the nature and appliances are but very little understood by the generality of practical men; and for this reason, every operation into which they enter is less or more involved in obscurity and mystery, and it is but seldom that the practical calculator can be induced to place implicit reliance on the results obtained by a process that he does not clearly comprehend, and which he cannot apply with readiness and ease.

It is not our intention in the present instance to investigate the formulæ on which the calculations depend; this has already been done, in a very elegant manner, by numerous writers on the subject of the arch, and consequently a repetition of the process is quite unnecessary in this place; we shall therefore adopt the formulæ as they have been supplied to us, and endeavour so to modify and arrange them, as to render them easily applicable by practical men in the various cases that come under their consideration.

It is a necessary condition of a railway arch, that the extrados should be a straight line parallel to the horizon, and the curve of equilibration having this condition involves two parameters, one of them entering as a coefficient, and the other as an exponent; this circumstance tends in no small degree to perplex the general theorem; and it is probably for this reason that the application of this species of the arch is so seldom to be met with, because the exponental parameter must always be determined by an independent process before the theorem for the co-ordinates can be applied; and this constitutes the chief difficulty of the operation.

In all cases where an arch has to be constructed, the data are, the span of the arch, the rise or height, and the thickness at the crown, or the depth of the key stone; the last of which, in the case of the equilibrated arch with a horizontal extrados, is the parameter which enters the equation by way of a coefficient; this, therefore, is always given *à priori*, and the other parameter is determined by computation from the three quantities here specified. The theorem for determining the exponental parameter or *modulus* of the curve, is *modulus* =

$$\frac{\textit{semi-span}}{2{\cdot}3025851 \times \textit{com. log.}\left\{\dfrac{\sqrt{(r+t)^2-t^2}+r+t}{t}\right\}}; \quad (A)$$

where r denotes the rise or height of the arch, t the thickness at the crown, or depth of the keystone, and 2·3025851 the hyperbolic logarithm of the number 10 in the decimal scale of notation, the semi-span denoting half the distance between the imposts or springings of the arch. The practical rule for reducing the equation marked (A) may be expressed in words at length as follows:—

RULE.—To the rise or height of the arch, add the thickness at the crown, or the depth of the keystone, and call this sum the greatest or extreme ordinate.

From the square of the greatest or extreme ordinate, subtract the square of the thickness at the crown, and extract the square root of the remainder.

To the square root of the remainder thus found, add the greatest or extreme ordinate, and divide the sum by the thickness at the crown, or the depth of the keystone.

Take out the common logarithm of the quotient, and to the logarithm of this logarithm, add the constant quantity 0·3622157 (which is also the logarithm of 2·3025851), and subtract the sum from the logarithm of the semi-span; then, the number corresponding to the remainder will be the exponental parameter, or the modulus of the equilibrated curve.

EXAMPLE.—The span of an arch is 96 feet, the height or rise 42 feet, and the thickness at the crown or the depth of the keystone 4 feet; it is required to determine the exponental parameter or modulus, on the supposition that it is an arch of equilibration, with a horizontal extrados corresponding to the line of railway.

Here by the rule we have, rise plus the thickness = 42 + 4 = 46 feet for the greatest or extreme ordinate, indicating the vertical distance between the impost, or springing of the arch and the roadway. The square of this is 46 × 46 = 2116, and the square of the thickness at the crown is 4 × 4 = 16; the difference of these is 2116 − 16 = 2100, and the square root of the remainder is $\sqrt{2100} = 10\sqrt{21} = 45{\cdot}82575$. To this add the extreme or greatest ordinate, and divide by the thickness at the crown, and we obtain (45·82575 + 46) ÷ 4 = 22·95644.

The log. of 22·95644 is 1·3609046, and the logarithm of this again, is 0·1338277; to which add the constant logarithm 0·3622157, and we get 0·1338277 + 0·3622157 = 0·4960434. Now half the span of the arch is 48 feet, and its logarithm is 1·6812412; the difference between these two logarithms, is 1·6812412 − 0·4960434 = 1·1851978, and the tabular number corresponding to the remainder, is 15·31785, which is the exponental parameter, or modulus of the equilibrated curve. It is in fact, the parameter of a catenary having the same horizontal axis or base, and its vertical axis in the same straight line with the proposed arch. The conditions of equilibrium of these two curves, are deduced directly the one from the other; the curve of equilibration and the catenary are therefore very nearly allied and may be referred to the same root; for when the two parameters of the equilibrated curve are equal between themselves, the general equation by which its nature is defined becomes the equation of the catenary.

The several steps of the preceding example have been drawn out in detail, in order the more clearly to shew the application of the rule as deduced from the equation involving the value of the modulus; but in that which follows we shall shew the several steps in combination, for the purpose of exhibiting how it is necessary to perform it in any particular case.

Example.—The span of an equilibrated arch with a horizontal extrados is 62 feet; the rise or height 42 feet, and the parameter or thickness at the crown 5 feet; it is required from these data to determine the modulus of the curve.

The greatest ordinate squared, is $(42+5)^2 = 47 \times 47 = 2209$

The least ordinate or parameter squared is . . . . $5 \times 5 = 25$

difference = 2184

the square root of which is,

$\sqrt{2184} = 46{\cdot}73328$

Greatest ordinate = 47

Sum = 93·73328, and divided by the least ordinate or parameter, it is

93·73328 ÷ 5 = 18·74666 . . . . log. 1·2729239

and of this the log. 0·1048024 } add
constant log. 0·3622157 }

log. 0·4670181 subtract

semi-span = 31 . . . . log. 1·4913617

Natural number or modulus = 10·57654 ft. . . log. 1·0243436

This, therefore, is the process which has to be performed in every case, where an arch is proposed to be constructed on the principles of equilibration; it is sufficiently easy in its application, and in order that the reader may become familiar with its use, he ought to resolve consecutively a number of examples proposed at random, as, by so doing, the mode of procedure would not only be firmly rooted in the mind, but the operator would become dextrous in applying the rule, and in consequence of such dexterity, would steer clear of errors, and acquire confidence in the result of his operations,—a very necessary condition when any thing of importance is dependent on his labours.

(*To be concluded in our next.*)